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1 Attorney Docket No. 75891

2
3 BOTTOM-DEPLOYED, UPWARD LOOKING HYDROPHONE ASSEMBLY

4
5 STATEMENT OF GOVERNMENT INTEREST

6 The invention described herein may be manufactured and used
7 by or for the Government of the United States of America for
8 Governmental purposes without the payment of any royalties
9 thereon or therefor.

10
11 BACKGROUND OF THE INVENTION

12 (1) Field of the Invention

13 The invention relates generally to hydrophone assemblies,
14 and more particularly to a hydrophone assembly that is to be
15 deployed on the bottom of a body of water for reception of
16 underwater acoustic signals.

17 (2) Description of the Prior Art

18 Tracking surface ship and underwater vehicles with
19 hydrophone systems is known in the art. For a complete view of
20 cooperative and uncooperative targets in a given area, such
21 hydrophone tracking systems are typically deployed on the bottom
22 of the particular body of water. To track various types of
23 vehicles, it is desirable for the hydrophone to have as broad a

1 receiving bandwidth as possible. Further, it is desirable that
2 the hydrophone system operate independent of its orientation on
3 the bottom of the water. To be useful in a variety of
4 application scenarios, the system should be portable in nature
5 and should be easy to place on and retrieve from the bottom of
6 the water, i.e., it should not require a specially designed
7 deployment vehicle or deep-water diving personnel. Ideally, each
8 hydrophone of the hydrophone system would also be modular in
9 nature to contain its own signal processing electronics. This
10 would allow the hydrophone system to be custom designed with as
11 many and/or as few hydrophones depending on the requirements of
12 the application.

13 Previous bottom-deployed tracking systems are deficient in
14 one or more of the above described design criteria. Prior art
15 hydrophones have avoided integrating the signal processing
16 electronics with the hydrophone owing to mechanical resonant
17 interference from the signal processing housing. Finally, the
18 prior art tracking systems are not designed for repeated
19 installations and therefore are not portable.

20

21 SUMMARY OF THE INVENTION

22 Accordingly, it is an object of the present invention to
23 provide a hydrophone assembly suitable for deployment on the

1 bottom of a body of water.

2 Another object of the present invention is to provide a
3 bottom-deployed hydrophone assembly having a broad operating
4 bandwidth.

5 Still another object of the present invention is to provide
6 a hydrophone assembly that can integrate signal processing
7 electronics with the hydrophone elements.

8 Yet another object of the present invention is to provide a
9 bottom-deployed hydrophone assembly whose operation is
10 independent of the orientation of the hydrophone assembly on the
11 bottom of a body of water.

12 Other objects and advantages of the present invention will
13 become more obvious hereinafter in the specification and
14 drawings.

15 In accordance with the present invention, a hydrophone
16 assembly for deployment on the bottom surface of a body of water
17 is provided. A hollow, cylindrical steel housing, designed to
18 hold signal processing electronics, has a central longitudinal
19 axis that lies substantially parallel to the bottom of the water.
20 A plurality of hydrophones are mounted in a spaced apart
21 relationship about the circumference of the housing. Each of the
22 hydrophones is constructed to detect a range of frequencies
23 within a defined receive angle that extends outward from the

1 circumference of the housing. A resonance absorbing material is
2 interposed between the housing and the hydrophones to isolate
3 each hydrophone from mechanical resonance of the housing. Tilt
4 switches are connected to each hydrophone for automatically and
5 independently selecting adjacent hydrophones to participate in
6 the output of the hydrophone assembly based on the orientation of
7 each of the hydrophones. The adjacent hydrophones define a
8 continuous receive angle associated with each adjacent
9 hydrophone. The continuous receive angle faces upward from the
10 bottom of the water to include an angular portion of the surface.
11 The size of the angular portion is dependent upon the overall
12 requirements of the hydrophone assembly.

13 14 BRIEF DESCRIPTION OF THE DRAWINGS

15 Other objects, features and advantages of the present
16 invention will become apparent upon reference to the following
17 description of the preferred embodiments and to the drawings,
18 wherein:

19 FIG. 1 is a cross-sectional view of a preferred embodiment
20 bottom-deployed, upward looking hydrophone assembly according to
21 the present invention;

22 FIG. 2 is a perspective view of the hydrophone element used
23 in the preferred embodiment of the present invention; and

1 FIG. 3 is a diagrammatic representation of an end view of
2 the preferred embodiment as it is deployed on the bottom of a
3 body of water such that two of its hydrophone elements are
4 activated.

5
6 DESCRIPTION OF THE PREFERRED EMBODIMENTS

7 Referring now to the drawings, and more particularly to FIG.
8 1, a cross-sectional view is shown of the hydrophone assembly,
9 referenced generally by numeral 10, according to a preferred
10 embodiment of the present invention. By way of example,
11 hydrophone assembly 10 will be described relative to its role in
12 the U.S. Navy's Portable Tracking System (PTS). In this role,
13 hydrophone assembly 10 is part of an in-line multiplexed bottom-
14 deployed sensor system. This system must detect acoustic signals
15 within an angular sweep of at least 120° looking upwards from the
16 system towards the surface of the water. The system must be
17 acoustically sensitive in the 8kHz-40kHz frequency range while
18 deployed in water depths up to 600 meters. However, as will be
19 readily apparent to one skilled in the art, the novel, features
20 of the present invention apply equally as well to other
21 hydrophone assemblies that are part of sensor systems having
22 different system requirements.

23 In FIG. 1, hydrophone assembly 10 integrates the hydrophone

1 element(s) and signal processing electronics by means of a single
2 structure. Hollow cylindrical steel housing 12 forms the
3 protective housing for signal processing electronics 100 that
4 processes signals received by hydrophone assembly 10.
5 Electronics 100 can comprise any standard signal processing
6 equipment associated with hydrophones that is well known in the
7 art (e.g., preamplifier, filters, multiplexer, processor, optical
8 electronics, etc.). Thus, it is to be understood that
9 electronics 100 is not a part of the present invention. The
10 output of electronics 100 is typically output on line 110 which
11 can be electrical lead or optical fiber. Alternatively, the
12 output from electronics 100 can be a "wireless" transmission.
13 Accordingly, it is to be further understood that the method
14 and/or apparatus used to transmit the output from electronics 100
15 is not a part of the present invention.

16 Housing 12 also forms the structural building block for
17 hydrophone assembly 10. Specifically, housing 12 is provided
18 with cylindrical recess 14 receiving resonance absorbing material
19 16 therein. Cylindrical recess 18 is provided in resonance
20 absorbing material 16 for receiving a plurality (of which two
21 appear in FIG. 1) of hydrophones 20 spaced apart from one another
22 within cylindrical recess 18 about the periphery of hydrophone
23 assembly 10. Hydrophones 20 are potted in place with an

1 acoustically transparent polyurethane 22. The outer surface of
2 hydrophone assembly 10 formed by resonance absorbing material 16,
3 polyurethane 22 and hydrophones 20 is then covered with neoprene
4 rubber skin 24 as a final sealant/protector. The output from
5 each of hydrophones 20 is transmitted on a corresponding signal
6 cable 26 to signal processing electronics 100. Electrical
7 conductivity between each hydrophone 20 and electronics 100 along
8 a corresponding one of signal cables 26 is dependent upon the
9 electrical conductivity of a corresponding tilt switch 28. In
10 other words, tilt switch 28 controls whether or not the output
11 from the respective hydrophone 20 will be passed to electronics
12 100. Signal cables 26 pass through to housing 12 by means of
13 hermetic seal 30. Finally, depending on the thickness of
14 resonance absorbing material 16 and tilt switches 28, transition
15 pieces 32 at either end thereof can be used to streamline the
16 profile of hydrophone assembly 10.

17 In order to provide the broad bandwidth capability required
18 for the illustrative example, each of hydrophones 20 is
19 constructed as shown in the perspective view of FIG. 2.
20 Hydrophone 20 is a laminated structure formed by two
21 piezoelectric elements 201 and 202 sandwiched about a common
22 electrode 203 that is connected to signal cable 26. Each of
23 elements 201 and 202 respectively includes piezoelectric material

1 2010 and 2020 sandwiched respectively by electrodes 2011/2012 and
2 2021/2022. Electrodes 2011 and 2021 are electrically connected
3 to one another via line 204. Each of elements 201 and 202 are
4 circular in shape to provide a uniform beam pattern in all
5 receiving directions about main response axis 205 which is normal
6 to the surface of hydrophone 20. A variety of piezoelectric
7 materials can be selected for piezoelectric material 2010 and
8 2020. However, for the bandwidth constraints imposed by the
9 illustrative example, each piezoelectric material 2010 and 2020
10 is a flexible piezoelectric composite material such as lead
11 titanate particles embedded in a neoprene rubber matrix. This
12 material is known in the art as PZR ("piezorubber"). This
13 composite material provide good sensitivity while its flexible
14 nature permits the use of simple fabrication processes.

15 As mentioned above, it is desirable to provide a compact
16 design that integrates the hydrophone element(s) and the
17 hydrophone's signal processing electronics. This eliminates the
18 need for underwater cables or connectors and therefore increases
19 the overall reliability of the hydrophone assembly. However, the
20 rigid (steel) housing 12 mechanically resonates at its natural
21 frequency (and harmonics thereof) and is therefore a source of
22 acoustic interference if housing 12 is in acoustic contact with
23 hydrophones 20. (The particular resonance frequency is inherent

1 to the physical dimensions of housing 12.) One solution is to
2 vary the dimensions of housing 12 so that the resonances are
3 shifted in frequency away from the receiving bandwidth of
4 interest, i.e., outside the 8kHz-40kHz listening range for the
5 illustrative example. However, as bandwidth requirements
6 increase, such resonance shifting can complicate the overall
7 design of housing 12. Thus, the present invention isolates each
8 of hydrophones 20 from the mechanical resonances of housing 12 by
9 means of resonance absorbing material 16. In terms of the
10 illustrative example, resonance absorbing material 16 is a
11 material having particles of lead embedded in a syntactic foam
12 made from silicon rubber.

13 Since hydrophone assembly 10 is to be deployed on the bottom
14 of a body of water for monitoring ship and underwater traffic,
15 hydrophone assembly 10 need only have a maximum acoustic
16 beamwidth of 180° that runs parallel with the surface of the
17 water. Practically speaking, and in terms of the illustrative
18 example, an acoustic beamwidth on the order of 120° (looking
19 upward towards the water's surface) is sufficient to monitor
20 ships and underwater vehicles over a board area of the water's
21 surface. Thus, hydrophone assembly 10 need only be acoustically
22 active over a relatively small angle that faces substantially

1 upward from the bottom of the water. Unfortunately, if
2 hydrophone assembly 10 were designed to receive only over the
3 specified angle, placement of hydrophone assembly would require
4 special positioning equipment/personnel thereby complicating the
5 assembly's deployment and minimizing its value as a repeated-use
6 hydrophone assembly.

7 One solution to the problem of requiring specialized
8 positioning equipment/personnel is to make the deployed
9 hydrophone assembly acoustically active over 360° by using either
10 an acoustic ring hydrophone or a plurality of hydrophones spaced
11 around the periphery of the hydrophone assembly. However, each
12 of these options generates distortion due to diffraction as
13 acoustic signals reflect from the bottom surface of the water.

14 The present invention solves the problem of distortion due
15 to diffraction by incorporating tilt switches 28 to govern the
16 conductivity along each of signal cables 26. Each of tilt
17 switches 28 is configured such that only those of hydrophones 20
18 necessary to provide the required (receiving) acoustic beamwidth
19 are activated once hydrophone assembly 10 is deployed on the
20 bottom of the water. In terms of the illustrative example, each
21 of tilt switches 28 is conductive only within $\pm 22.5^\circ$ of a line
22 normal to the water's surface. Thus, tilt switches 28 allow the

1 passage of signals (received by the correspondingly connected
2 hydrophone 20) to electronics 100 based on the orientation of the
3 correspondingly connected hydrophone 20. Each of tilt switches
4 28 can be implemented by any one of a variety of well known
5 mechanical, mercury, etc., tilt switches.

6 The advantages afforded by the use of tilt switches 28 is
7 best understood by describing the operation of the present
8 invention as it pertains to the illustrative example. In FIG. 3,
9 hydrophone assembly 10 is shown diagrammatically from one end
10 thereof as it is deployed on bottom 301 of body of water 300.
11 Once deployed, the longitudinal axis 11 of hydrophone assembly 10
12 is parallel with bottom 301. For purpose of the illustrative
13 example, eight hydrophones 20 are equally spaced (i.e., main
14 response axes 205 are spaced apart from one another by 45°) about
15 the periphery of hydrophone assembly 10. If each of hydrophones
16 20 is constructed as described above with reference to FIG. 2,
17 each of hydrophones 20 has an individual acoustic beamwidth of
18 approximately 120° balanced symmetrically about the respective
19 main response axis 205. Accordingly, no more than two adjacent
20 ones of hydrophones 20 need ever be participating in the output
21 of hydrophone assembly 10 to achieve an upwardly-directed
22 acoustic beamwidth of $120-180^\circ$ (balanced about line 302 normal to

1 surface 303). Note that for the illustrative embodiment, there
2 is a possibility that only one of hydrophones 20 need be
3 activated. This scenario would occur only if hydrophone assembly
4 10 deployed itself on bottom 301 such that one main response axis
5 205 were perpendicular to the surface of water 300-a condition
6 that is not likely to occur.

7 The advantages of the present invention are numerous.
8 Signal processing electronics are integrated with the hydrophone
9 element(s) thereby providing a compact modular hydrophone
10 assembly that provides good sensitivity while minimizing
11 distortion due to mechanical resonances of the assembly itself.
12 Further, the present invention can be easily deployed, e.g.,
13 dropped from the water's surface, as an individual element or as
14 part of a sensor array cable since orientation of the hydrophone
15 assembly will automatically activate only those hydrophones
16 needed to achieve an overall acoustic beamwidth. The automatic
17 hydrophone activation minimizes losses due to diffraction between
18 adjacent hydrophone elements. Finally, the structure and
19 material used in the individual hydrophone elements provides a
20 broad operating bandwidth not currently available.

21 It will be understood that many additional changes in the
22 details, materials, steps and arrangement of parts, which have
23 been herein described and illustrated in order to explain the

- 1 nature of the invention, may be made by those skilled in the art
- 2 within the principle and scope of the invention,
- 3

1 Attorney Docket No. 75891

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3 BOTTOM-DEPLOYED, UPWARD LOOKING HYDROPHONE ASSEMBLY

4
5 ABSTRACT OF THE DISCLOSURE

6 A hydrophone assembly for deployment on the bottom of a body
7 of water is provided wherein a plurality of hydrophones are
8 mounted in a spaced apart relationship about the circumference of
9 a housing which is designed to hold signal processing
10 electronics. Each hydrophone is constructed to detect a range of
11 frequencies within a defined receive angle that extends outward
12 from the circumference of the housing. A resonance absorbing
13 material is interposed between the housing and the hydrophones to
14 isolate each hydrophone from mechanical resonance. Tilt switches
15 are connected to each hydrophone for automatically and
16 independently selecting hydrophones to participate in the output
17 of the hydrophone assembly based on the orientation of the
18 hydrophones. Selected adjacent hydrophones define a continuous
19 receive angle formed by combining the receive angle associated
20 with each adjacent hydrophone. The continuous receive angle
21 faces upward from the bottom of the water to include an angular
22 portion of the surface.

FIG. 1

10

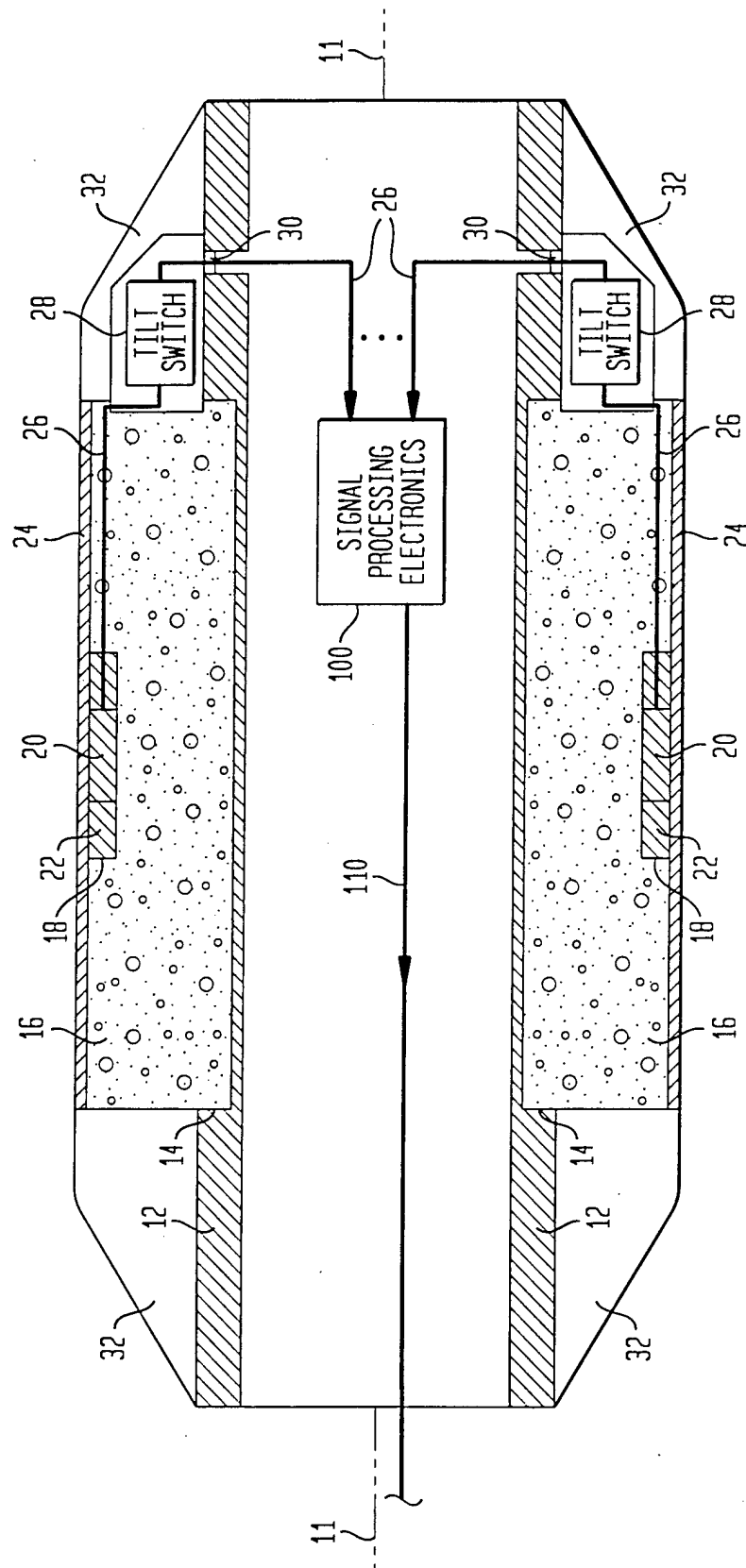


FIG. 2

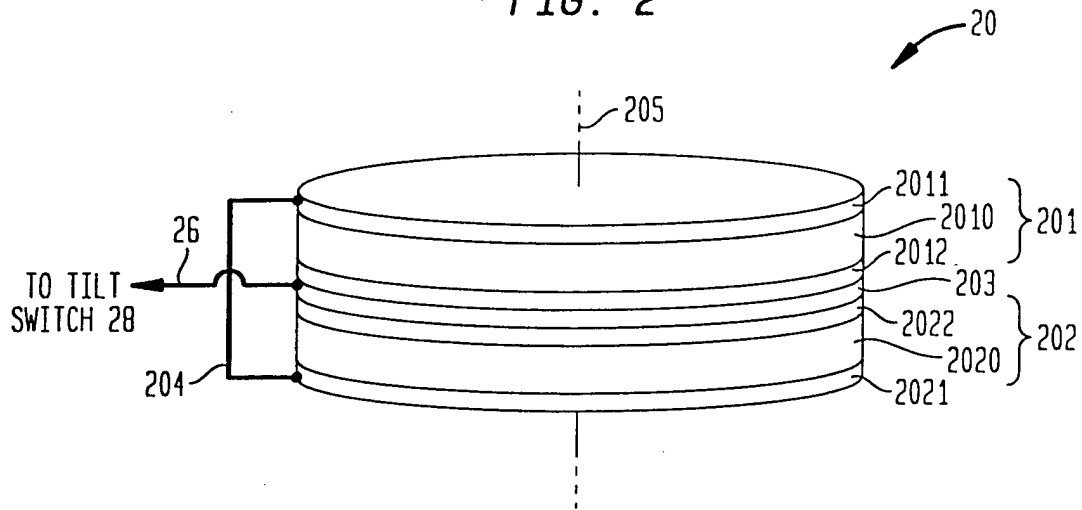


FIG. 3

